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A NOTE ON THE MEASUREMENT OF CONDITIONAL DISCRIMINATION

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An analysis of some extreme forms of stimulus control that a simple conditional-discrimination procedure can generate leads to the conclusion that accuracy does not provide an orderly scale of measurement. Dependence on accuracy to evaluate a conditional discrimination, particularly at intermediate levels of accuracy, can generate erroneous conclusions about the extent to which the controlling relations are those specified by the experimenter.

Key words: conditional discrimination, stimulus control, measurement

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A subject's performance on a conditional discrimination is often measured by accuracy, the combined probability of correct responses in the presence of each conditional stimulus. A conditional-discrimination procedure may, however, generate many controlling relations, and these require a more complete analysis than accuracy provides. Cumming and Berryman (1965), for example, have demonstrated stimulus and key "preferences" and other "hypotheses" that may interact with desired forms of control. Signal detection analysis has shown that the measurement of "correct" responses can lead to misleading conclusions if one does not take "response bias" into account (Goldiamond, 1964). Major purposes of the present note are to analyze still further some of the types of stimulus control that a simple conditional-discrimination procedure can generate and to examine the limitations of accuracy as a measure of conditional discrimination.

An example of a simple conditional discrimination is one in which vertical and horizontal lines serve as simultaneous discriminative stimuli, with green and red hues as conditional stimuli. When the conditional stimulus is green, the vertical discriminative stimulus is arbitrarily designated as positive; the subject's response to it is correct, and a response to horizontal is an error. When the conditional stimulus is red, vertical becomes negative, and a response to horizontal is correct. Given the two controlling relations in which the lines are discriminative stimuli, the one to be considered correct on any particular trial is conditional on a third stimulus, the hue.

To perform this task correctly, a subject must discriminate the lines from each other, and the hues from each other, and the hues must control both a line discrimination and its reversal. Matrix A in Figure 1 illustrates a perfect conditional discrimination which meets all these requirements. The patterns of cell probabilities within each row demonstrate a line discrimination and its reversal; the probabilities within each column demonstrate two hue discriminations; the difference in the two patterns of row probabilities denotes a conditional discrimination, with the hues controlling the two different line discriminations. When the conditional stimulus is green, the subject always selects vertical and never horizontal; when the conditional stimulus is red, the line discrimination reverses and the subject always selects horizontal. It will be assumed that this conditional discrimination, to be called "Type-A control," is the one the experimenter wishes to establish.

Matrix A′ in Figure 1 illustrates another perfect conditional discrimination. All components of Matrix A are also in A′, but the correlation between the line discriminations and the conditional stimuli is the opposite of the one the experimenter specifies as correct. Now, when the conditional stimulus is green, the subject always selects horizontal; when it is red, the subject selects vertical.

Matrix B in Figure 1, with uniform cell probabilities, gives no indication that hues or

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lines exert differential control. One might infer that Matrix B represents random responding —no control by the specified stimuli or by any others. It will be assumed, however, that behavior is never undetermined, that all responses are controlled, if not by stimuli the experimenter has specified, then by others. Control may fluctuate from trial to trial so that it is difficult to measure, but this is not the same as random responding.

A second inference about Matrix B might be that the specified stimuli do exert control but the data are not homogeneous. If the discriminations fluctuate systematically, the total matrix might obscure the controlling relations. Trial subsets extracted from the total matrix could reveal such fluctuations, and all that would then be required for a more complete description would be a division of the data into separate matrices, one for each homogeneous subset. The concern here, therefore, will be with instances in which Matrix B and the others to be discussed below are homogeneous.

Even if we grant Matrix B to be homogeneous, we still need not interpret the performance as uncontrolled. A third possibility is that the experimenter-specified stimuli, hues and lines, do not enter into the controlling relations at all but that other stimuli do. For example, if the subject were always to select a single key, say the left key, regardless of the line that happened to be on it and no matter which hue was present, it would yield Matrix B.

With key position exerting complete control, the hues and lines would be irrelevant, perhaps even nonexistent for the subject. In that event, Matrix B would demonstrate the absence of differential control by those stimuli on which the experimenter's interest is centered, but it would tell nothing about the actual controlling relations. It may even suggest, incorrectly, that each specified controlling relation occurs on 50% of the possible occasions, and that the subject conforms to the experimenter-imposed contingencies on half of the trials, when in fact the controlling relations described in the matrix *never* occur, and the subject *never* meets the experimental contingencies.

Key position is not the only source of unspecified control that might produce Matrix B, but is a prototype of a highly probable controlling stimulus that the data matrix does not take into account. Since control by position has the advantage of being easily and frequently observed, it will be used again as an example in considering other patterns of control.

Matrix C, like Matrix B, shows no evidence of conditional control; changes in hue do not affect the subject's behavior. Unlike Matrix B, Matrix C does reveal a perfect line discrimination, one of the two illustrated in Matrix A but showing up here as a complete preference for vertical. Matrix C′ shows a similar pattern of control, but the preference is for horizontal.

Matrices A, A′, B, C, and C′ illustrate extreme examples of well-recognized forms of stimulus control that the conditional-discrimination procedure may generate. Matrices D and D′ combine features of the other matrices into yet another extreme form of control that has not been as well recognized. Like Matrix C, the upper row of Matrix D shows one of the two line-discrimination components of the desired Type-A control. Like Matrix B, the lower row of Matrix D suggests no control by the lines. Like Matrix A but unlike Matrices B and C, control by the lines is conditional upon the hues; when the conditional stimulus changes from green to red, differential control by the lines disappears. Matrix D′, similar to D, shows the other line discrimination and the opposite conditional relation to the hues.

The absence of differential control by the lines in Matrix B suggested an unspecified source of control. Similarly, the lower row of Matrix D suggests that an unspecified discrimination, in addition to the line discrimination shown in the upper row, might be under conditional control. Suppose the subject had been given the following instructions: "When you see red, ignore the lines and always select the key on the left; when you see green, ignore key position and always select the vertical line." A subject who followed these instructions would produce Matrix D, which then becomes an instance of perfect conditional control over two discriminations. Vertical is always selected in the line discrimination, and the left key in the position discrimination. If a subject had learned this conditional discrimination as a result of explicitly designed reinforcement contingencies, the experimenter would regard Matrix D as a perfect performance. Matrix D therefore is as extreme an

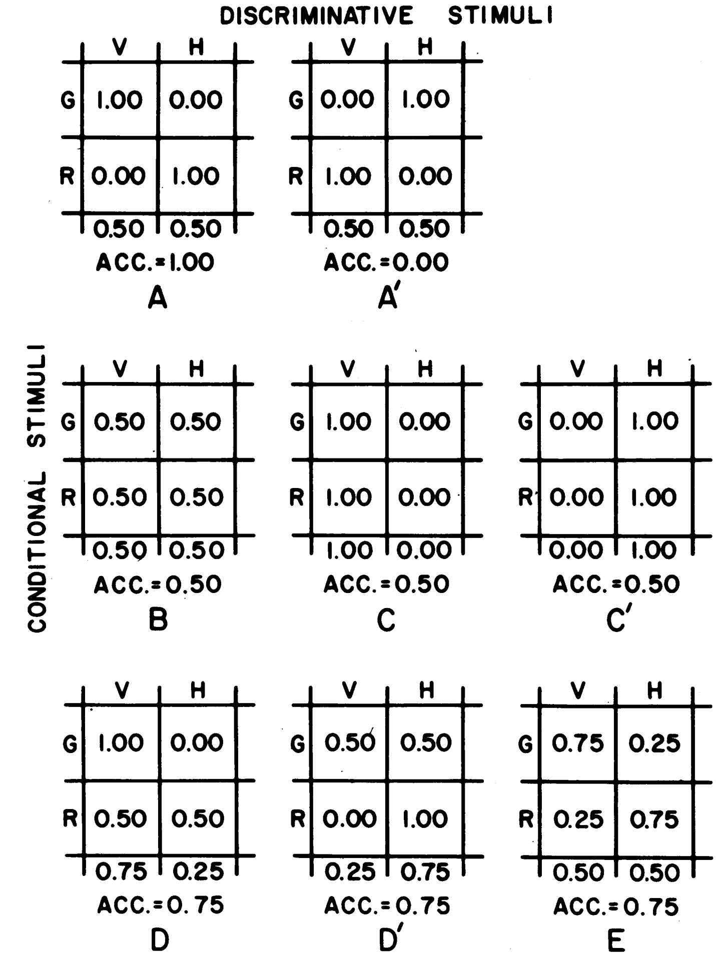

Fig. 1. Matrices illustrating types of performances that may be generated by a conditional-discrimination procedure. The stimuli are vertical (V) and horizontal (H) lines, and green (G) and red (R) hues. ACC. = accuracy.

example of Type-D control as Matrices A, B, and C are of Type-A, -B, and -C control.

How do these various forms of control, all generated by the conditional-discrimination procedure, order themselves along the accuracy scale? Matrices A and A′ each represent perfect conditional discriminations, with the specified stimuli exerting complete control. The components of Type-A and Type-A′ control are exactly the same except that the conditional relations are reversed. The extreme values of accuracy, 1.00 for Matrix A and .00 for A′, might be rationalized in either of two ways. The first would consider accuracy to be solely a measure of control by the specified conditional stimuli, green and red, but would not be concerned with the identity of the particular discriminations over which these stimuli exerted control. Any "indicators" of conditional control would be equally acceptable. This rationale would hold that Matrices A and A′ each represent equal conditionality, and would therefore require the assumption that accuracies of 1.00 and .00 are opposite but equivalent. The true zero on the accuracy scale would then be the "chance" level, .50.

For many purposes, the conditional discrimination of Matrix A′ is indeed just as useful as that of Matrix A. An experimenter who is concerned specifically to establish Type-A control, however, will regard Type-A′ control as a disaster. A second rationalization would therefore consider all components of the conditional control and would hold the extreme difference in accuracy between Matrices A and A′ to be a valid reflection of the extreme difference in the form of the conditional control. Zero would then represent the bottom of the accuracy scale.

If one conceptualizes accuracy according to the first alternative, which emphasizes only conditionality and places .50 at the bottom of the scale, one has no problem with Matrices B, C, and C′, all of which reflect a complete absence of conditional control and produce the "lowest" accuracy, .50. The second alternative, however, which emphasizes the desired form of conditionality and places .00 at the bottom of the accuracy scale, poses the problem of rationalizing a higher accuracy, .50, for Type-B control. If Matrix B were produced by a fluctuating pattern of Type-A and -A′ control, it might seem reasonable for the measure to yield a value halfway between A and A′. But it is not clear what sense it makes for Matrix A′, which denotes perfect but reversed conditional control by the specified stimuli, to be located at a lower point on the accuracy scale than Matrix B, which reflects no conditionality at all. A similar incongruity arises when one considers Matrices C and C′, which also yield an accuracy of .50 despite a complete absence of the desired conditionality.

Matrices D and D′ raise additional problems for both conceptions of accuracy. Conditional control by the hues over one line discrimination and one key-position discrimination is complete, yet accuracy is only .75. If accuracy is to be regarded solely as a measure of conditionality, independently of the particular indicator discriminations, then it becomes difficult to rationalize a lower accuracy for Matrices D and D′ than for A and A′.

The other conception, which regards accuracy as a measure of the desired conditional discrimination, raises the opposite problem: how is it possible to rationalize a higher accuracy for Type-D than for Type-A′ control? If Type-D control were to be regarded as partial Type-A control, then on what grounds could one claim that Matrix A bears a greater resemblance to Matrix D than to Matrix A′? Furthermore, a scale of measurement which assigns a value to any element of the desired form of control would have to give Matrices C and C′ a higher value than Matrix B.

Neither conception of accuracy, therefore, provides a scale for the measurement of conditional control that is continuous over the whole range of data matrices which the conditional-discrimination procedure may generate. If one conceptualizes accuracy solely as a measure of conditionality, independently of the particular conditional relations, and makes the required scale transformation, a discontinuity appears when one encounters Type-D (or D′) control. If one adopts the more restricted conception of accuracy as a measure of a particular form of conditional control, discontinuities become apparent not only for Type-D and D′ control but even for Types B, C, and C′.

The Type-D (or D′) discontinuity, like Type-B, arises because the data matrix from which accuracy is calculated does not specify key position as a possible controlling stimulus (again, only a likely one out of many possibilities). Matrix D suggests, incorrectly, that when the conditional stimulus is red, the subject responds to vertical (or horizontal) on 50% of the possible occasions. In fact, when the conditional stimulus is red, the subject *never* responds to vertical or horizontal but ignores the lines and responds to key position. The measures of stimulus preference, the marginal column probabilities, are therefore also deceptive. Matrix D, for example, suggests that the subject selects vertical on 75% of the total trials, but it actually does so only on trials with a green conditional stimulus—50% of the total trials. Matrices B, D, and D′ are anomalous in that they provide seemingly objective measures of controlling relations which actually do not exist. The other side of this anomaly, of course, is the failure of these matrices to measure the controlling relations which actually do exist.

Even in signal-detection analysis, which makes no direct use of accuracy, the substantial response bias in Matrix D (or D′), derived from the difference between the two error probabilities, is subject to misinterpretation. If the subject actually is ignoring the lines in the presence of the red conditional stimulus, the bias must be considered to be an artifact of the experimenter's incorrect assumptions about the actual controlling stimulus. Although Matrix B can be located at the upper edge of the signal-detection space, halfway between Matrices A and C, its location there will be meaningless if the assumed controlling relations are nonexistent.

Matrices A through D′, then, reflect extreme forms of control that cannot be placed in order along the accuracy scale. To the extent that matrices which are seemingly intermediate between these extremes also reflect unwarranted assumptions about the actual controlling relations, the appearance of continuity can also be misleading. Can one say, for example, that Matrix E is halfway between Matrix B and Matrix A when Matrices B and A, to start with, are not on the same scale? A possible metric for ordering the extreme forms of control might be derived from an experiment in which subjects are first taught to behave in accord with each matrix except A, and then are shifted to the contingencies which are appropriate to Matrix A. What effect would each history or combination of histories have on the rate at which Type-A control emerged, and on the intermediate patterns of control through which the performance would pass on the way to Type-A control? Whether subjects with the same history would reveal sufficient consistency to support a reliable scale of measurement is at best problematic. Until a rational basis for continuity can be established, however, the most reasonable working assumption must be that the extreme forms of control are completely different from each other, in the sense that any elements taken from differing continua are different.

The discontinuity between Type-D (or D′) and Type-A control can have particular damaging consequences if an experimenter accepts accuracy in the range of 75% as the criterion for successful learning—a practice that is not unusual. The problem can be highlighted by comparing Matrices D and E (or D′ and E), each of which yields an accuracy of .75. Matrix D represents a conditional discrimination, a perfect example of its type but not the desired one. Matrix E also represents a conditional discrimination which, although imperfect, is of the desired form. All the component controlling relations in Matrices A and E are the same, differing only quantitatively. In Matrices A and D, on the other hand, the component controlling relations are different in kind: only one of the desired line discriminations is present; an unwanted key-position discrimination is present; and the conditional stimuli control these two discriminations rather than the line discrimination and its reversal.

A subject, therefore, who achieves an accuracy of .75 via Type-D control is not equivalent to a subject who achieves the same accuracy via Type-E control. If an investigation of acquisition carries the subjects only to accuracy levels near .75, and fails to evaluate the data for Type-D (or D′) control, one cannot be certain that the particular conditions of the study have succeeded at all in generating the desired form of conditional control. Furthermore, experiments that establish baseline accuracies in the range of .75, and then go on to evaluate transfer effects, must yield equivocal findings if it is assumed that the baseline performances of all subjects are equivalent.

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